NASA's Balloon Program Update

Astrophysics Advisory Committee

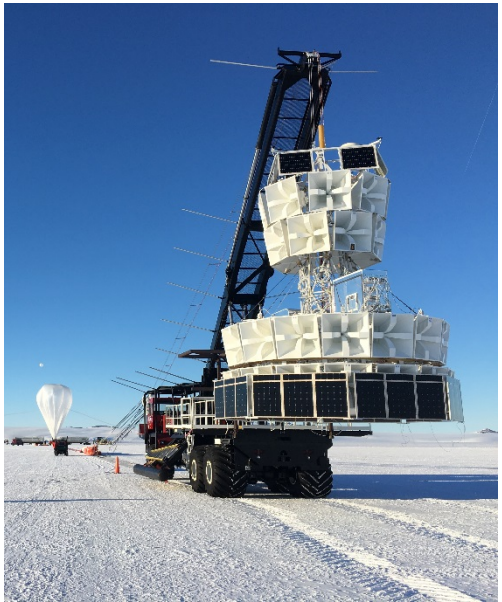
Debora Fairbrother
April 11, 2018

Goddard Space Flight Center

Mission of the NASA Balloon Program

Wallops Flight Facility

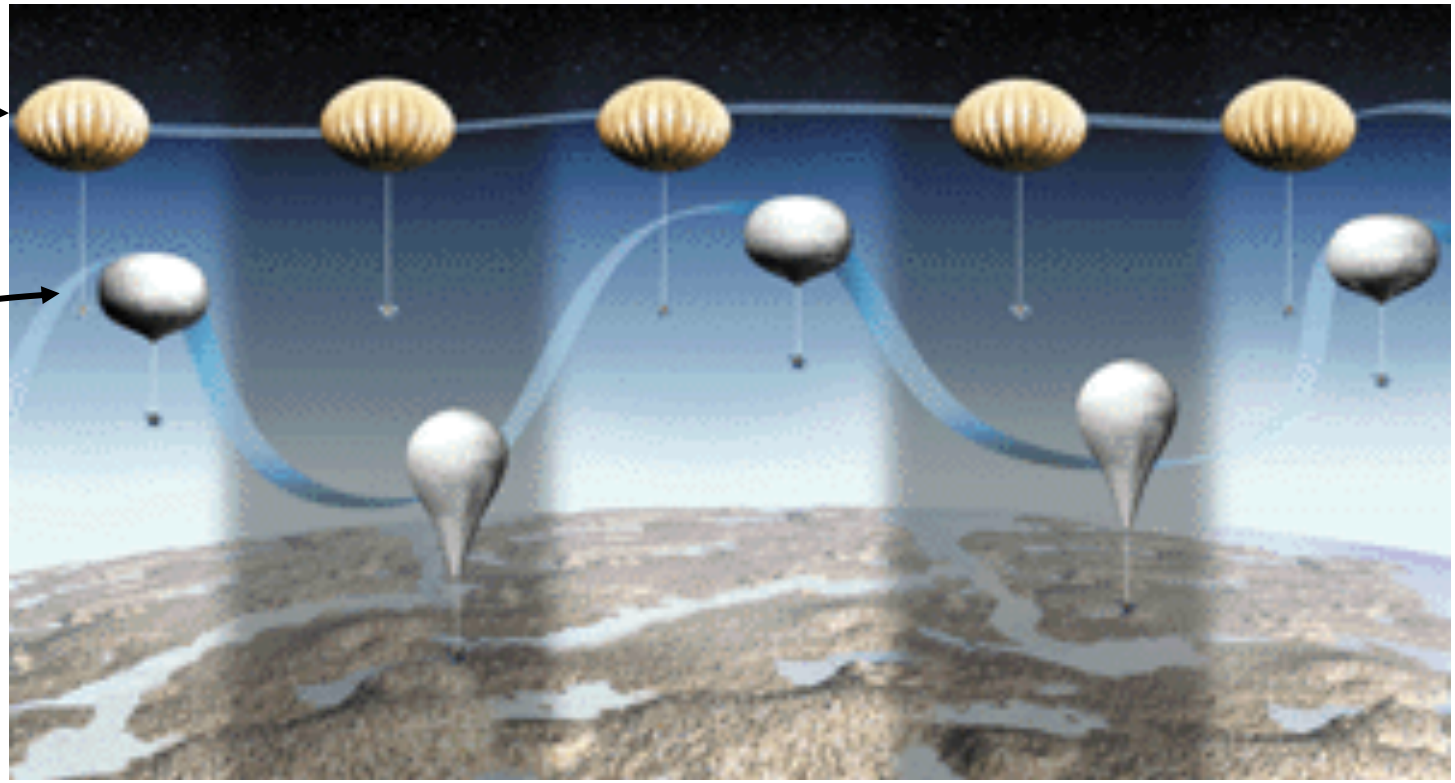
- The NASA Balloon Program provides low-cost, quick response, near space access to NASA's science Community for conducting Cutting Edge Science Investigations
- Serve as a technology development platform
- Excellent training for NASA scientists and engineers



Two Types of Balloons

Super Pressure Balloon maintains nearly constant volume – ***under development***

- Allows Ultra Long Duration Balloon (ULDB) Flights
- Provides stable altitude Long Duration Balloon (LDB) flights at mid-latitudes

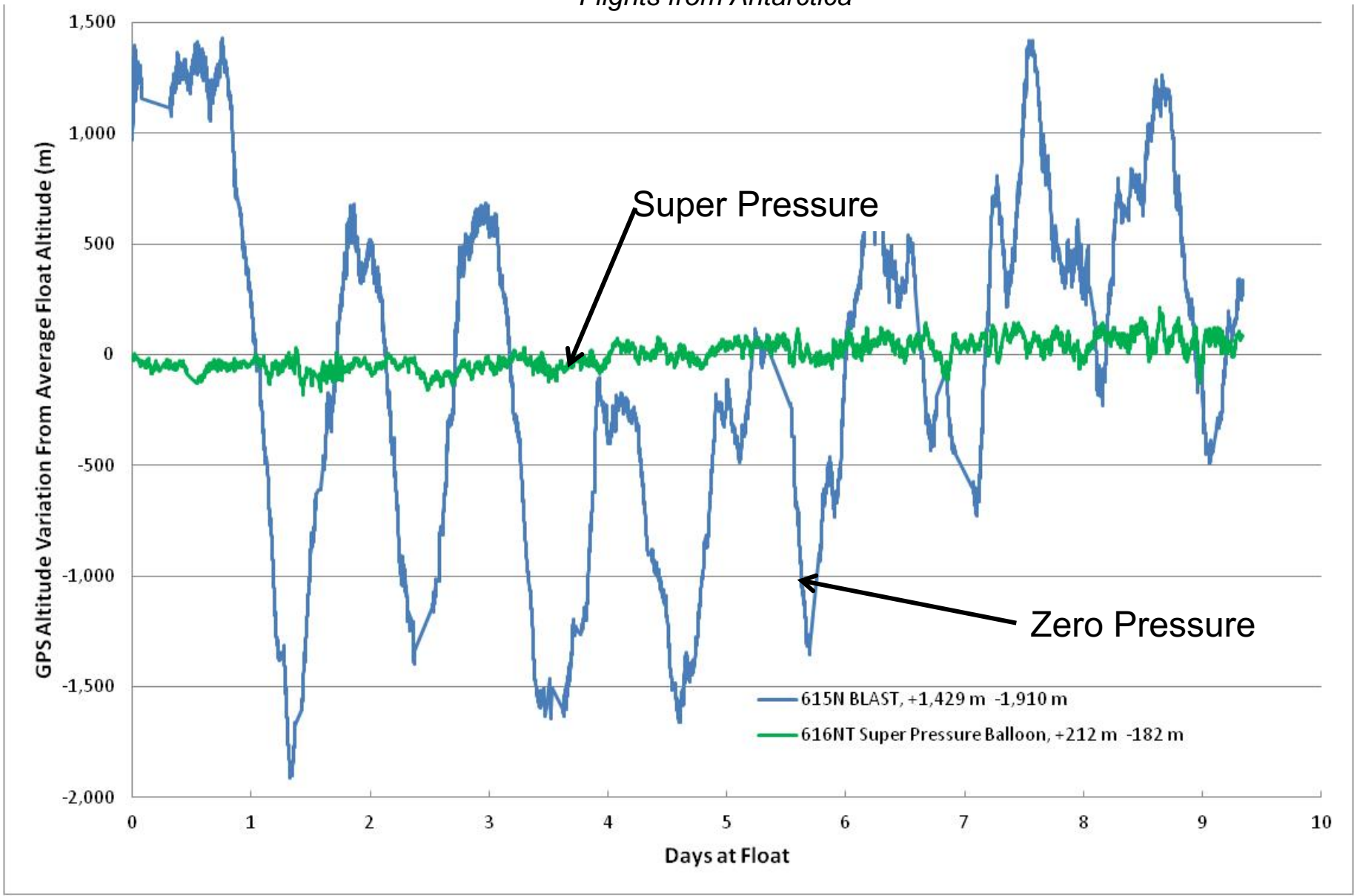


Zero-Pressure (ZP) Balloon changes volume due to radiative input

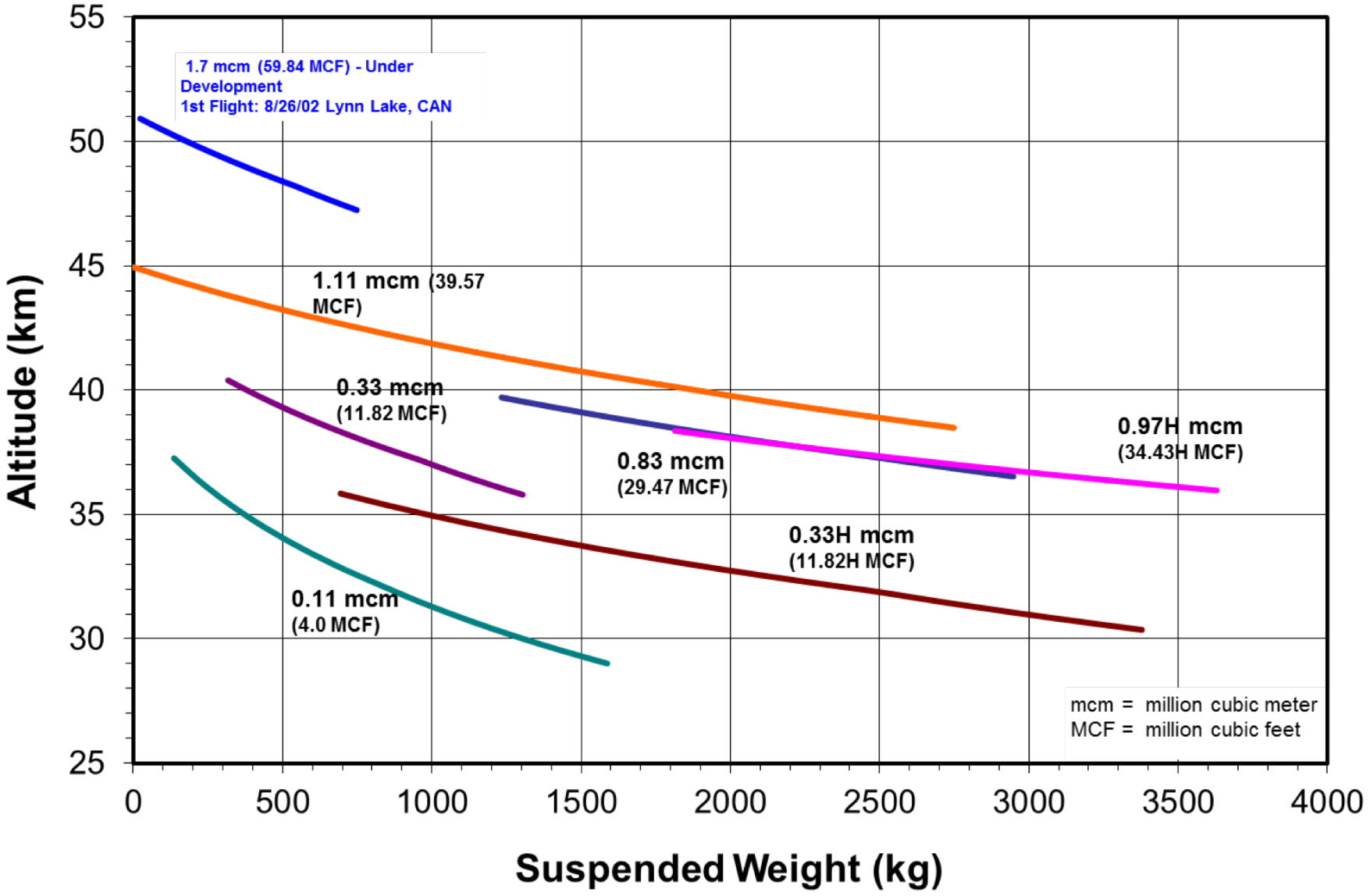
- Used for Conventional Flights and Polar LDB Flights

Polar Altitude Stability Comparison

Flights from Antarctica



ZP Load Altitude Curves



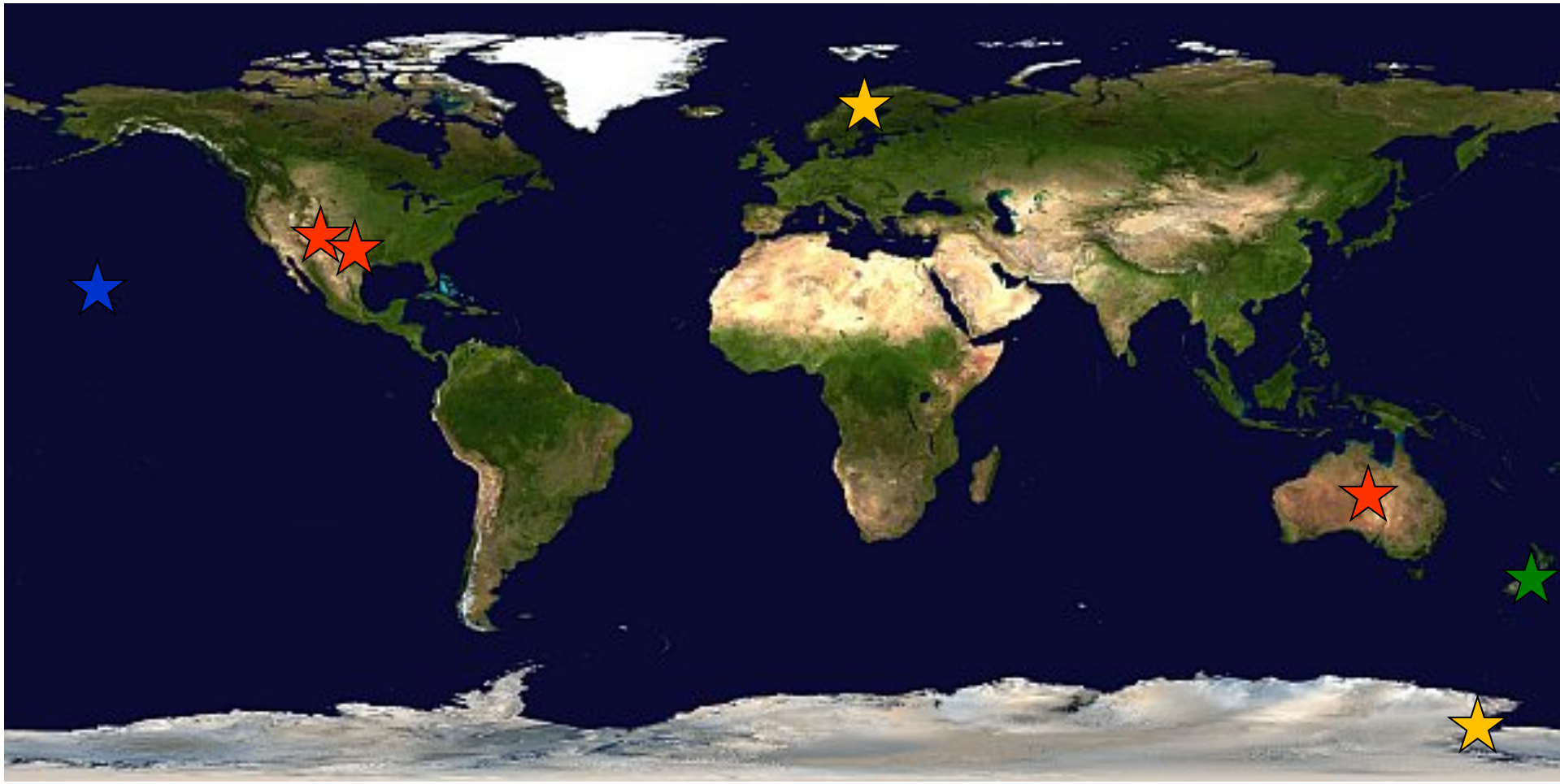
Capabilities

Balloon Type	Zero Pressure (ZP)	ZP	Super Pressure (SP)– In Development
Mission Type	Conventional	LDB	LDB / ULDB
Duration	2 hours to 3 days	Typical 5-15 days Up to 55+ days	Up to 100 days
Science Payload Weight	Up to 2,721 kg (Up to 6,000 lb)	Up to 2,721 kg (Up to 6,000 lb)	0.53 mcm (18.8 mcf) – 907 kg (2,000 lb)
Total Suspended Weight	Up to 3,630 kg (Up to 8,000 lb)	Up to 3,630 kg (Up to 8,000 lb)	0.53 mcm (18.8 mcf) – 2,268 kg (5,000 lb)
Typical Float Altitude	29.2 to 38.7 km (96 to 127 kft)	36.5 to 38.7 km (120 to 127 kft)	0.53 mcm (18.8 mcf) – 33.5 km (~110 kft)
Support Package	**Consolidated Instrumentation Package (CIP)** ○ Line of Sight (LOS) ○ Up to 1 Mbps direct return	**Support Instrumentation Package (SIP)** ○ Over The Horizon (OTH) ○ 6 kbps TDRSS downlink ○ 100 kbps option with TDRSS or Iridium	
	Micro Instrumentation Package (MIP) ○ Stand alone package for small payload support ○ LOS and OTH TM & Command (Iridium) 255 byte/min packets ○ Up to 1 Mbps LOS option System without batteries ~9 kg (20 lb)		
Launch Locations	Fort Sumner, NM; *Palestine, TX*; Alice Springs, Australia; *PMRF, Hawaii*	Antarctica; Kiruna, Sweden	Antarctica; Wanaka, New Zealand

SPB Video from Sweden

Launch Locations

World-wide Operations



Palestine, Texas

Columbia Scientific Balloon Facility (CSBF)

- Established by National Center for Atmospheric Research in 1962
- Government Owned Contractor Operated Facility
- Primary Facilities for Support Contractor
- Conventional Flights
- Payload Staging and I&T Support
- Operations Control Center (OCC)

CSBF Aerial

Fort Sumner, New Mexico

Conventional Fall Campaign (annually) **and Conventional Spring Campaign** (as needed)

- Flight durations from 4 to 24+ hours
- 2-9 missions supported each campaign
- Science, Technology, Education and Test Flights
- Missions of Opportunities Available

Esrange, Sweden

Northern Hemisphere Long Duration Balloon (LDB) Campaign (as needed)

- Established in 2005 (Sweden to Canada)
- Flight durations on the order of 4 to 6 days
  - Duration could be extended with Russian Overflight approval
- 1-4 missions supported each campaign
- Esrange World Class Facilities & Support

Alice Springs, Australia

Southern Hemisphere Conventional Campaign
(as needed)

- 1-2 missions supported each campaign
- Flight durations of 1 to 3 days
- Launch operations on Alice Springs Airport
- Limited support provided by CSIRO/Univ. New South Wales

McMurdo, Antarctica

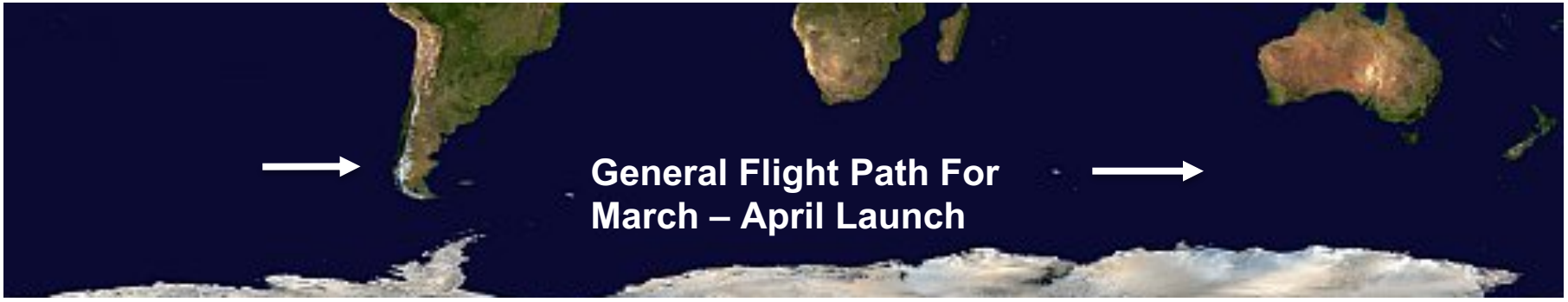
Southern Hemisphere Polar Long Duration Balloon (LDB) Campaign (annual)

- Established in 1989
- Collaboration with National Science Foundation (NSF)
- 2-3 missions supported each campaign
- Flight durations from 7 to 55+ days
- Launch operations at LDB Site on Ross Ice Shelf outside of McMurdo Station
- Recovery coordinated with NSF
  Winter-over of instrument possible

Wanaka, New Zealand

Southern Hemisphere Long Duration Balloon (LDB)/ Ultra Long Duration Balloon (ULDB) Campaign

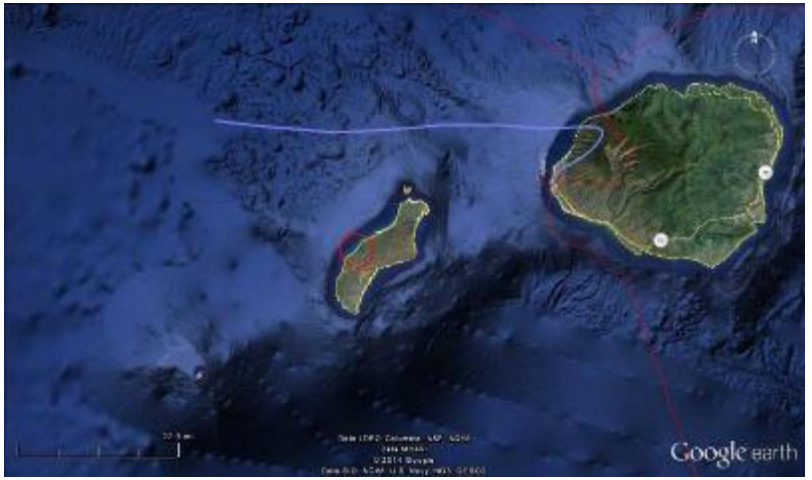
- Established in 2015
- Flight durations 10 to 100 days
- Launch Operations on Wanaka Airport
- Safety: Active Risk Assessment Required for Mission
- Limited Payload Dimensions due to Leased Hangar – Overguide Received to Build Larger Building To Accommodate Larger Missions



Kauai, Hawaii

Pacific Missile Range Facility

- First Launch in 2014
- Platform Support for Low Density Supersonic Decelerator (LDSD) Project
- Static Launch Tower Utilized
- Water Recovery of Balloon
- Launch Tower Disassembled and Shipped to CSBF



Super Pressure Development

The NASA Super Pressure Balloon (SPB) is being developed to provide a stable platform at constant density altitude for extended duration science investigations at polar and mid-latitudes.

Volume	Suspended Weight	Altitude	Flight Number	Duration	Launch Date	Landing Location
7 MCF	1,500 Lbs	~110 KFT	591 NT	54 days	Dec 28, 2008	Antarctica
14.9 MCF	4,000 Lbs	~110 KFT	599 NT 608 NT 616 NT	4.2 hours 2.8 hours 22 days	June 22, 2009 Dec 10, 2009 Jan 9, 2011	Sweden Antarctica Antarctica
18.8 MCF ***Primary Science Interest***	5,000 Lbs 5,000 Lbs 5,000 Lbs 5,000 Lbs 5,500 Lbs	~110 KFT	631 NT 659 NT 662 NT 669 NT 679 NT	6.5 hours 43 hours 32 days 46 days 12 days	Aug 14, 2012 Dec 28, 2014 Mar 26, 2015 May 16, 2016 April 24, 2017	Sweden Antarctica Australia Peru Pacific Ocean
26 MCF	4,000 Lbs	~117 KFT				

Several science groups are requesting a suspended weight of 5,500 pounds on the 18.8 MCF; therefore, some future test flights will have higher suspended weights when appropriate.

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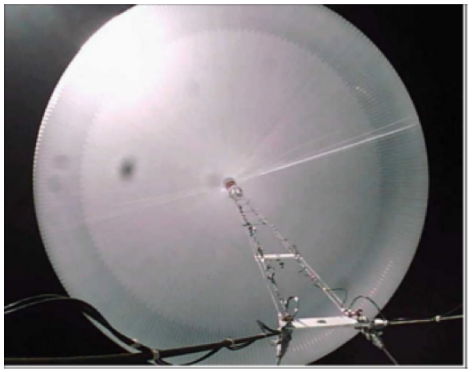
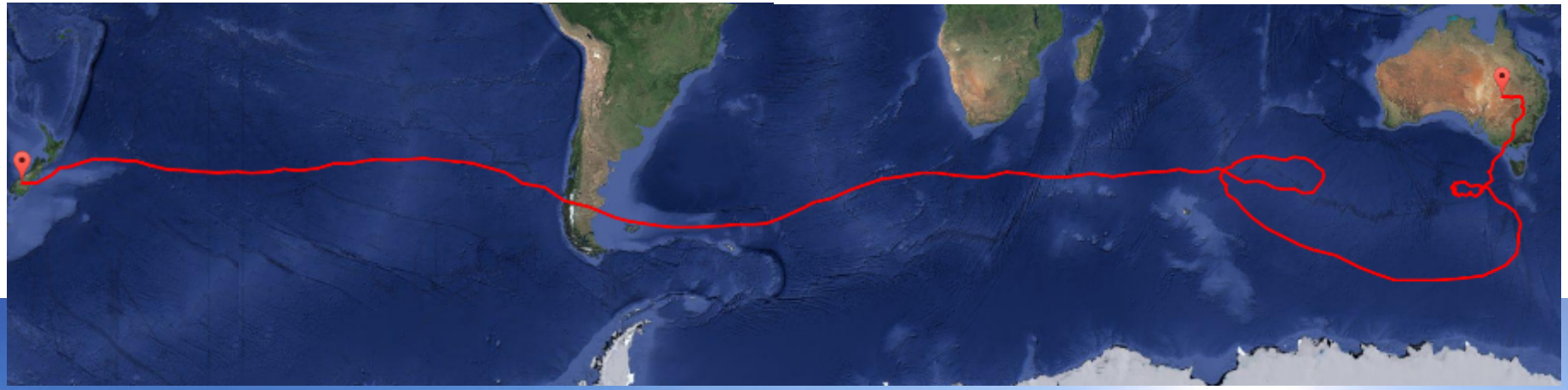
2015 - 18.8 MCF SPB

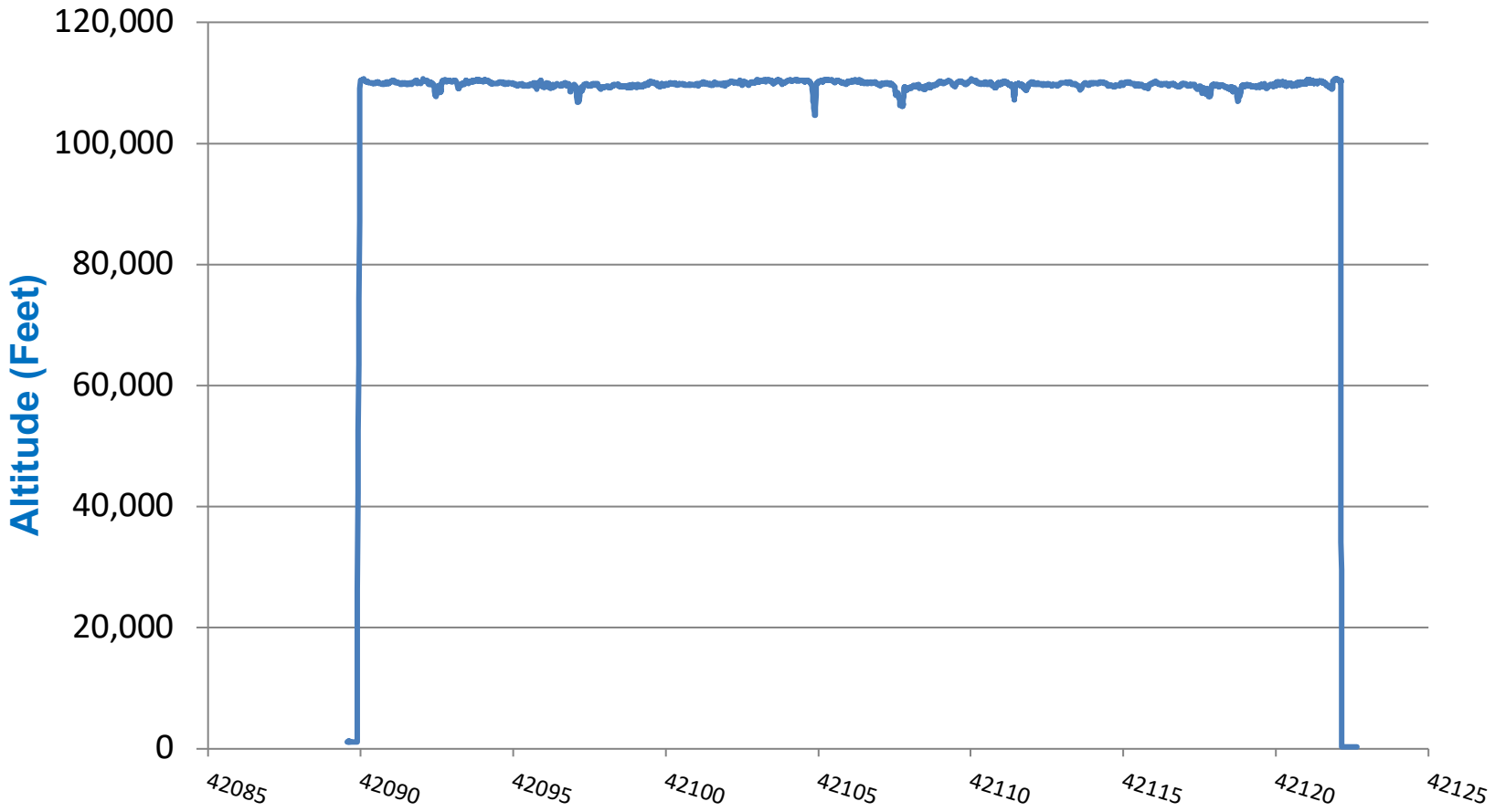
Wallops Flight Facility



- Launch Site: Wanaka, New Zealand
- Volume: ~532,152 m^3 (~18,793,000 ft^3)
- Launch Date: March 26, 2015
- Suspended Load: 2,268 kg (5,000 lbs.)
- Flight Time – 32 Days, 5 hours, 51 minutes
- First multi-day diurnal flight!

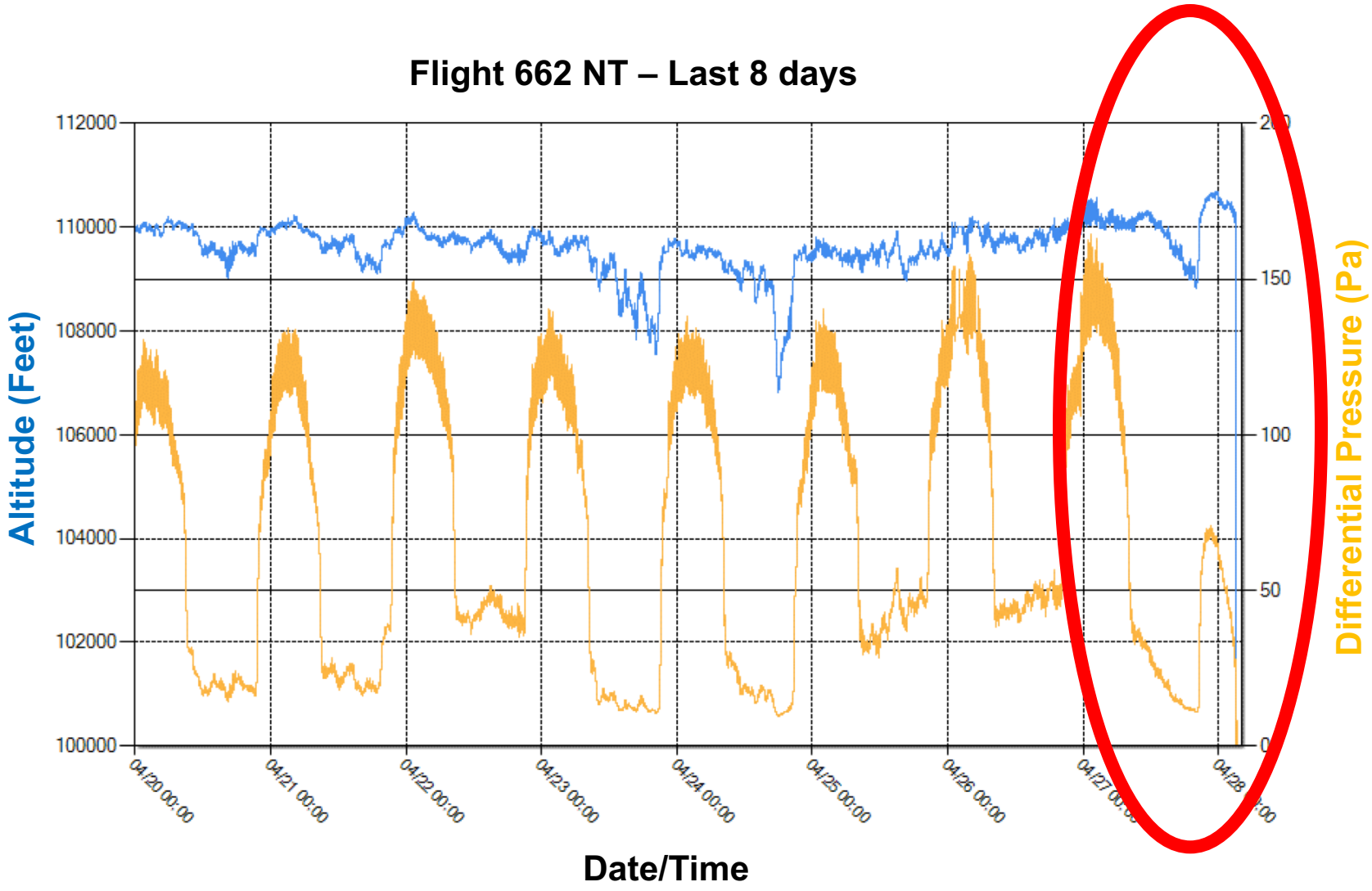


2015 - 18.8 MCF SPB



Flight performance of this balloon was exceptional
Total flight time was 32 days 5 hours 51 minutes, a record for this size balloon at these altitudes at these latitudes for this duration

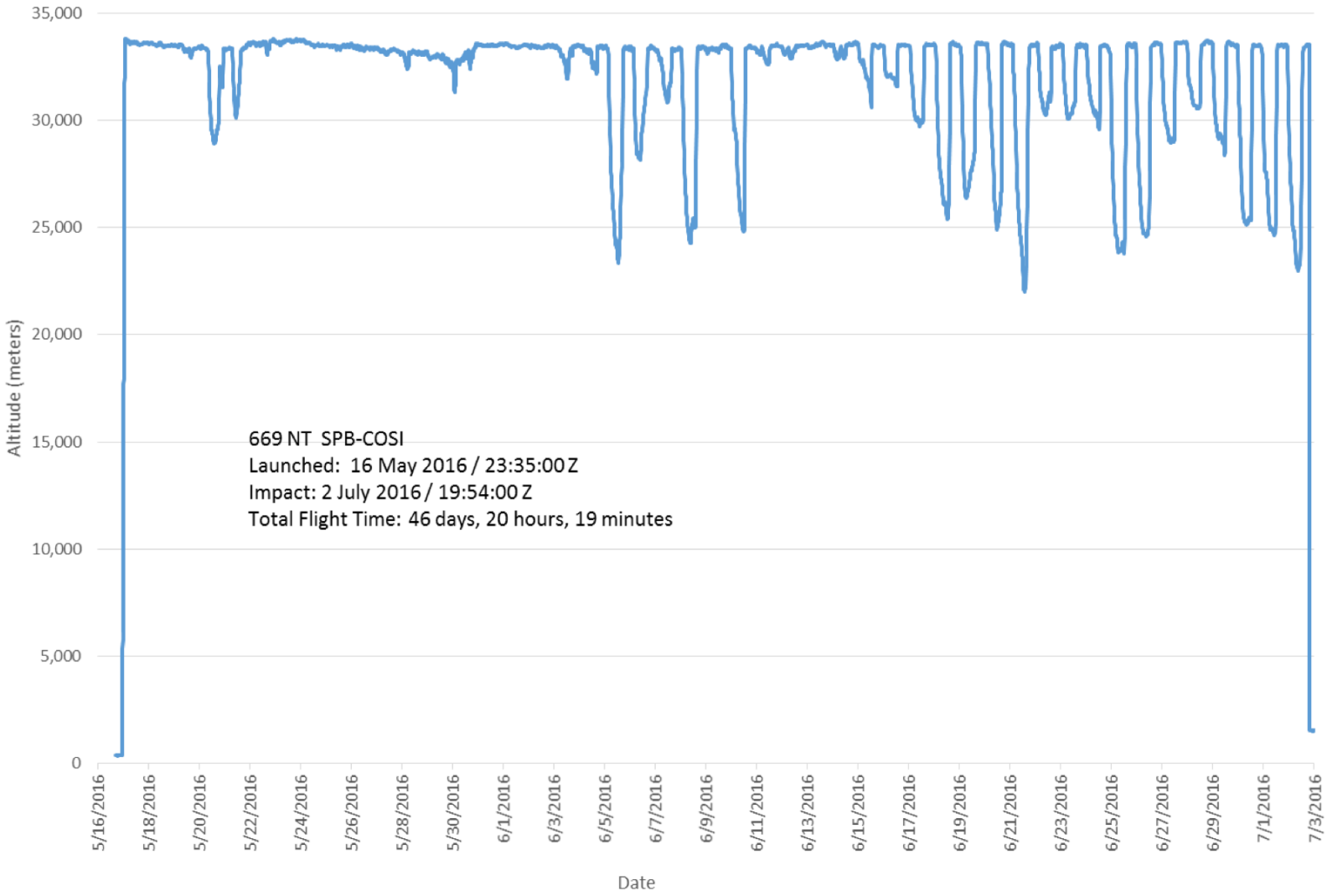
2015 - 18.8 MCF SPB



2016 - 18.8 MCF SPB

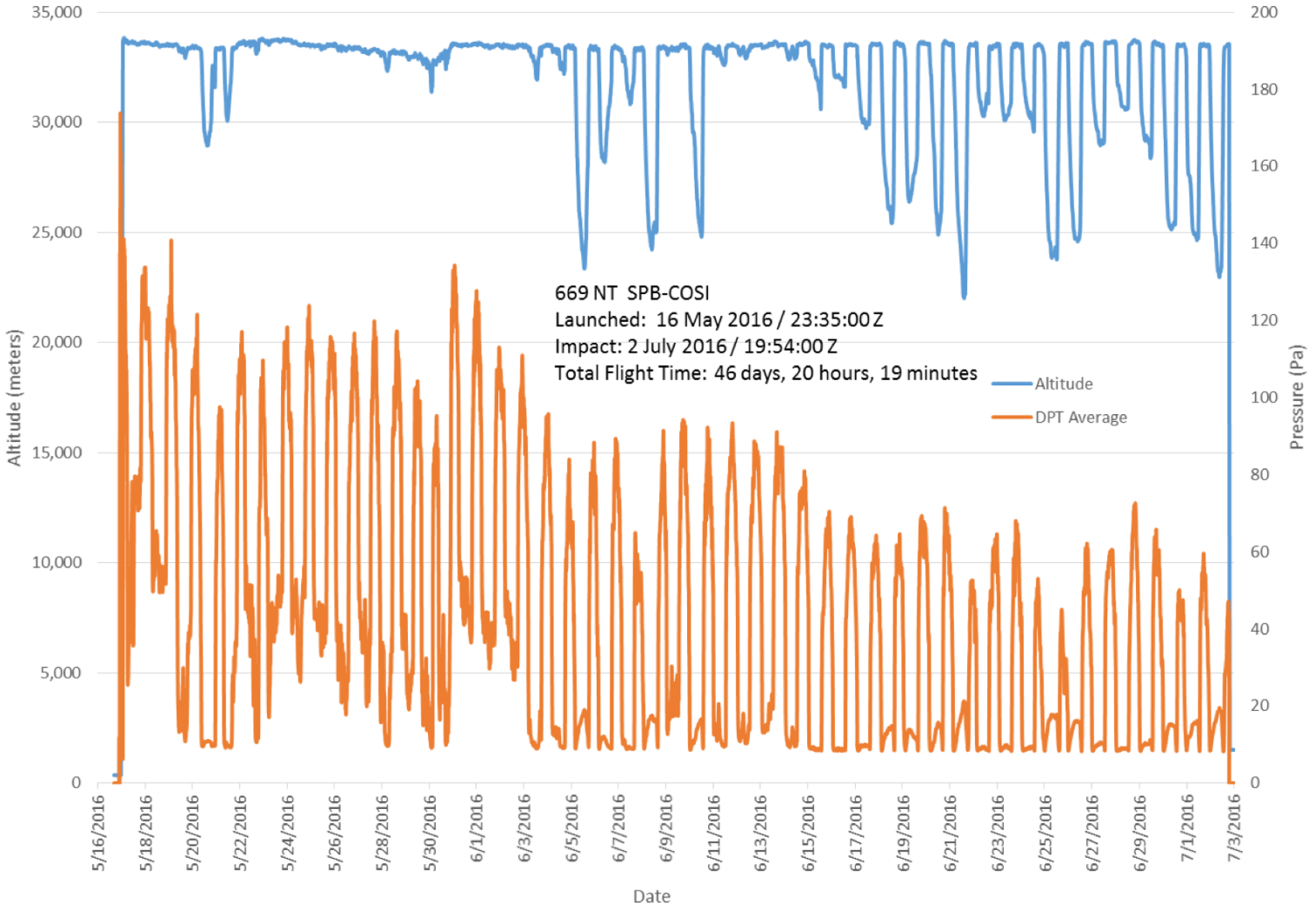
- Launch Site: Wanaka, New Zealand
- Volume: ~532,152 m^3 (~18,793,000 ft^3)
- Launch Date: May 16, 2016 @ 23:35 Z
- Suspended Load: 2,268 kg (5,000 lbs.)
- Flight Time – 46 Days, 20 hours, 19 minutes
- Flying the Compton Spectrometer and Imager (COSI) as a Mission of Opportunity

2016 - 18.8 MCF SPB



Lowest Altitude During Flight ~ 22 km Due to Loss of Gas During Flight.

2016 - 18.8 MCF SPB



The Balloon Performed as a Hybrid – SPB During Day – ZP at Night Later in the Mission.

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2017 - 18.8 MCF SPB

Wallops Flight Facility

- Launch Site: Wanaka, New Zealand
- Volume: ~532,152 m^3 (~18,793,000 ft^3)
- Launch Date: April 24, 2017 @ 22:50 Z
- Suspended Load: 2,495 kg (5,500 lbs.)
- Flight Time – 12 days, 4 hours, 34 mins
- Flying the Extreme Universe Space Observatory (EUSO) as a Mission of Opportunity

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2017 - 18.8 MCF SPB

Wallops Flight Facility

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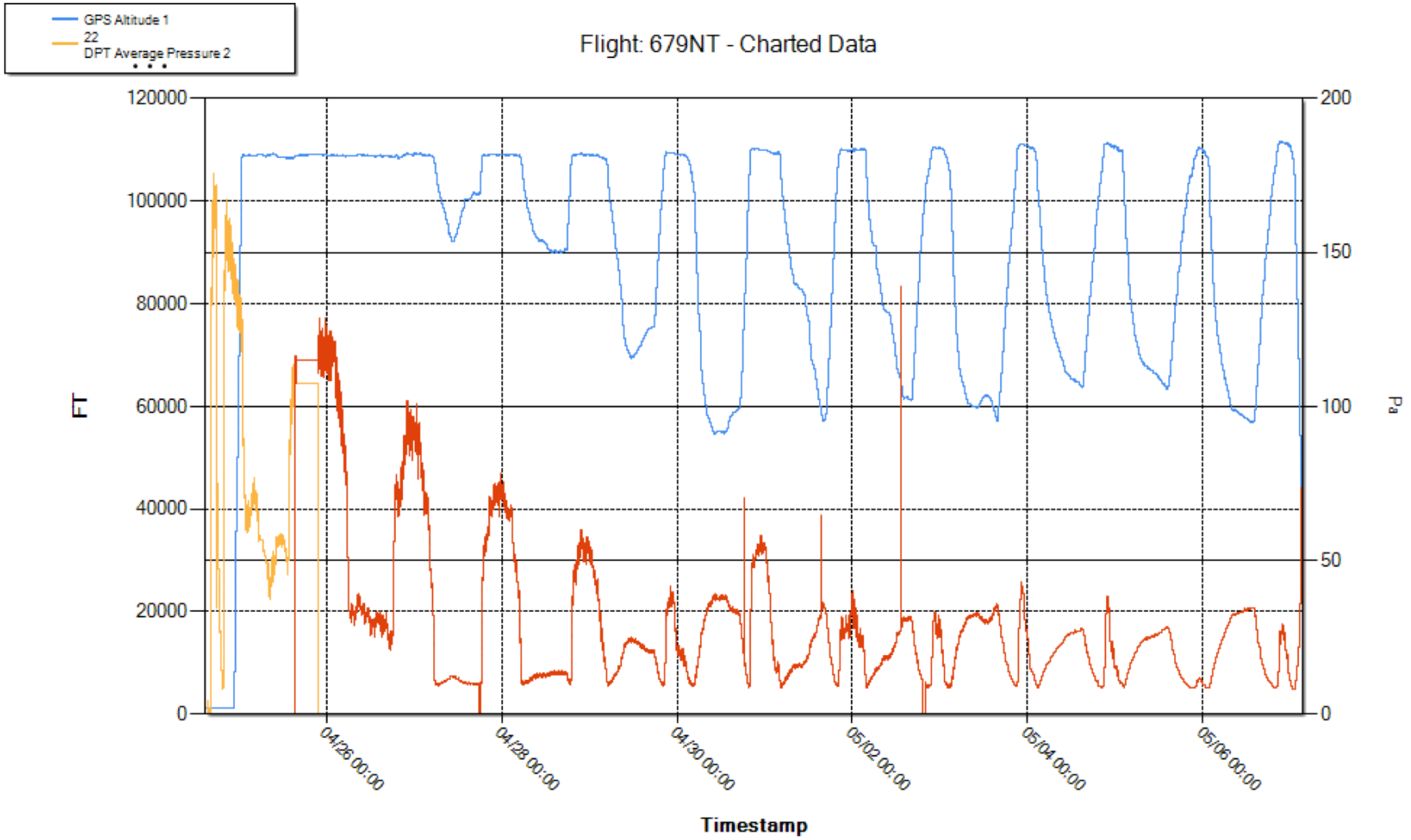
2017 - 18.8 MCF SPB

Wallops Flight Facility



Initially, 1,200 pounds of ballast – dropped over 1,100 pounds of it in drops on 4/29, 4/30, 5/1, 5/3, and 5/6

Super Pressure Next Steps

Instrumentation Team: *The Instrumentation Team has been reformed to research and test additional instrumentation that can be flown on SPB and ZP flights. Collaborating with NASA Engineering & Safety Center Sensors and Instrumentation Technical Discipline Team.*

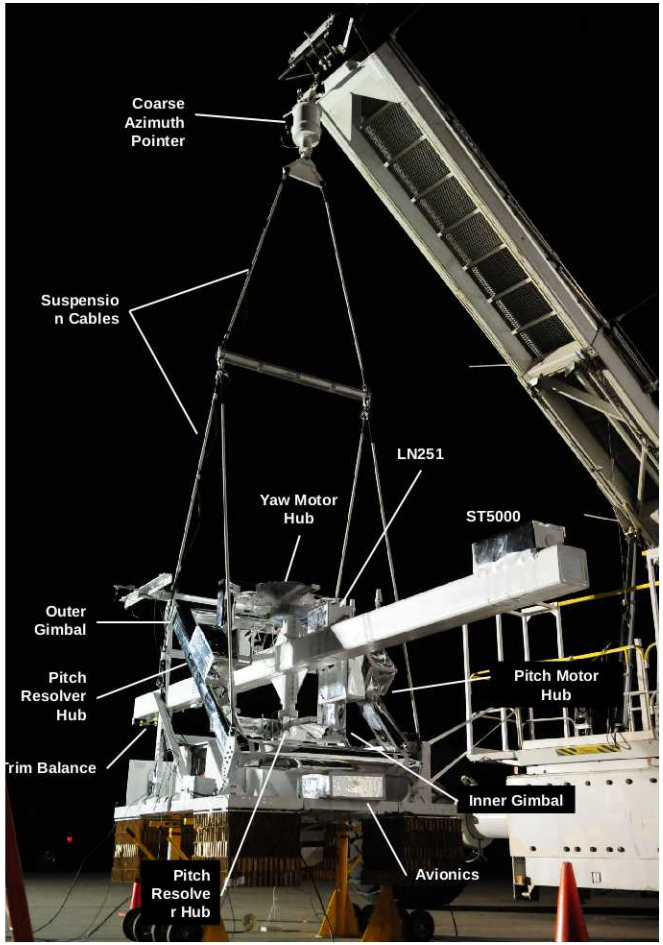
Leak Testing: *WFF is continuing to conduct leak testing on fitting components. Recent testing on helium valve.*

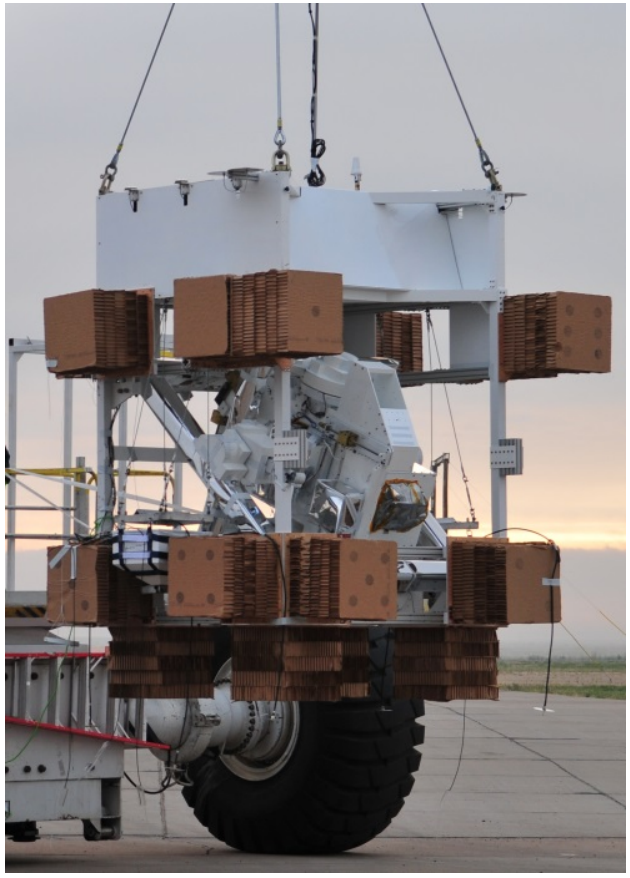
Scaled Balloon: *Design and analysis of scaled balloons for ground inflation tests.*

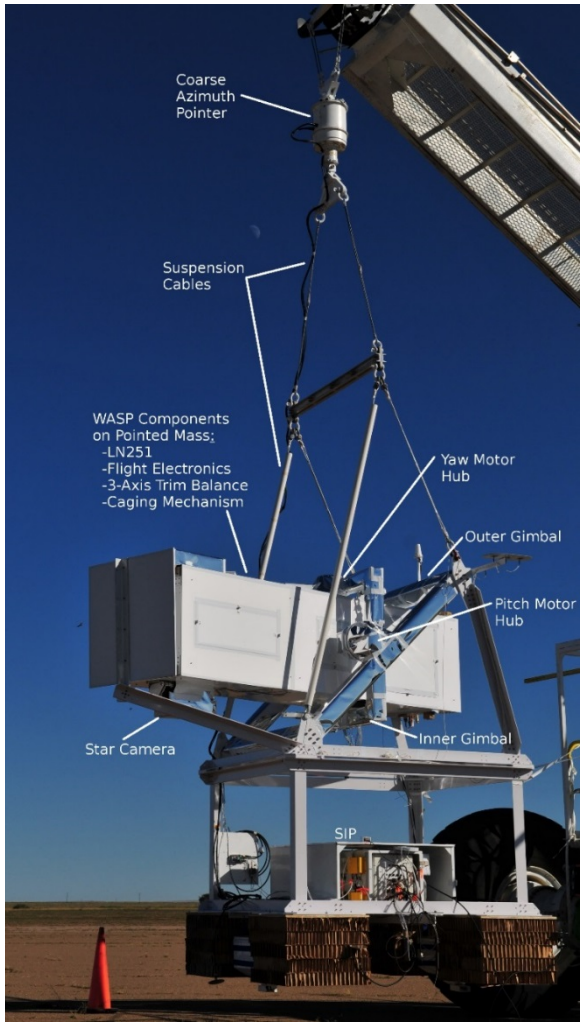
Fitting Design Modifications*: Optimization to balloon apex and base fitting design to reduce mass and accommodate instrumentation.*

Wallops Arc Second Pointer (WASP)

WASP is an in-house technology development effort to develop and qualify a control system capable of pointing balloon-borne instruments at inertial targets with arc second accuracy. To date, WASP has flown five test flights, some with science piggyback, and one operational science mission. It is operational and currently supporting three science missions.

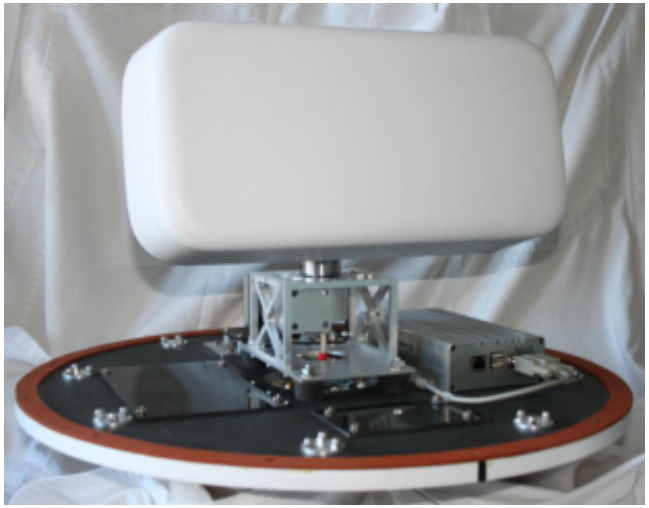






Additional Technology Developments

- Improved Rotator
- TDRSS High Gain Antenna
- WFF TDRSS Low-Cost Transceiver (LCT2)
- Charge Controllers
- Valence Lithium Iron Phosphate Batteries
- Indoor Iridium Repeaters
- 60 MCF Balloon (1,400 pounds to 157 kft)



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FY17 Flight Manifest

Wallops Flight Facility

Principal Investigator (PI) / Institution / Instrument	Discipline	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
McMurdo, Antarctica	**Winter 16**													
Seo / UMD / BACCUS	Cosmic Ray / Particle				SUCCESS									
Gorham / UH / ANITA	Cosmic Ray / Particle				SUCCESS									
Besson / UK / ANITA HiCAL (HL)	Cosmic Ray / Particle				SUCCESS / SUCCESS									
Walker / UA / STO-2	IR-Submillimeter				SUCCESS									
Wanaka, New Zealand	**Spring 17**													
Fairbrother / WFF / SPB / Olinto / Chicago / EUSO	Test / Cosmic Ray									ANOMALY				
Palestine, Texas	**Summer 17**													
Rinehart / GSFC / BETTII	IR-Submillimeter										CLOSE CALL			
Jones / Princeton / SuperBIT	UV / Visible								ABORT 27			CAMPAIGN		
Kogut / GSFC / PIPER	IR-Submillimeter											STANDDOWN		
Fort Sumner, New Mexico	**Fall 17**													
Guzik / LSU / HASP	Student Flight Project										SUCCESS			
Kogut / GSFC / PIPER	IR-Submillimeter											SUCCESS		
Jones / Princeton / SuperBIT - Postponed to FY18	UV / Visible													
Stuchlik / WFF / WASP - Postponed to FY18	Test Flight													
Martin / CalTech / FIREBALL - Postponed to FY18	UV / Visible													
Toon / JPL / Remote - Postponed to FY18	Upper Atmosphere													
Fischer / WFF / Big 60 - Postponed to FY18	Test Flight													
Moore / WFF / USIP - Postponed to FY18	Student Flight Project													

Recent Close Calls and Mishaps

Date/NMIS Number	Category	Event	Source
5/18/17 17-100830	Close Call	CSBF battery pack malfunction	Science Team Modification
6/9/17 17-100948	Close Call	BETTII Balloon Payload Failure	Science Rotator
7/17/17 17-101221	D	Employee twisted ankle stepping down from platform.	CSBF Employee
9/11/17 17-101419	Close Call	CSBF team member received electrical shock	Science Ground Support Equipment
9/11/17 17-101611	Close Call	Science team did not don appropriate PPE for a hazardous operation	Science Team Hazardous Op
9/13/17 17-101625	Close Call	During the flight line check out of the CSBF chute cutaway system, an electrical arc was observed by the electrical technician.	CSBF Flight Hardware
9/17/17 17-101652	Close Call	When changing out power outlets on building UPS system, one circuit breaker was mislabeled on panel.	CSBF Contractor
10/18/17 17-101848	D	Employee fell off ladder	CSBF Employee

= *Resulted in stand down of operations*

Process Improvements

As a result of the recent collar anomalies and close calls, the BPO has initiated the following Process Improvements:

CSBF:

- Development of Interim Collar Electronics Package
- Reorganization of CSBF Staff
- Non-Conforming Reports (NCR) with Corrective Actions
- Connector Selection
- Training
- Quality Assurance

Science Team:

- Battery Safety
- Ground Support Equipment
- Power Systems
- Hazardous Procedures

Process Improvements Cont.

Gondola Design and Certification

- Formalize and Conduct Gondola Design Reviews with all science teams
- The CSBF Structural Design Specifications will be updated to a NASA Specification.
- Establish reflight requirements for flight hardware (Inspection/Non-destructive testing)
- Establish ground support equipment requirements for science teams

Balloon Program Office

- WFF Senior Leadership Oversight (Frank Bellinger) of Process Improvements
- Hired Chief Technologist & Working on Hiring Two Mission/Technology Managers
- Establish Technical Interchange Meetings with Science Teams after award
- Development of Final Collar Electronics Package

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FY18 Candidate Manifest

Wallops Flight Facility

Principal Investigator (PI) / Institution / Instrument	Discipline	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
McMurdo, Antarctica	**Winter 17**									
Binns / WUSTL / SuperTIGER	osmic Ray / Particle	⇨		**MANIFESTED FY19**						
Esrange, Sweden	**Summer 18**									
Clem / UDel / AESOP-lite	Heliophysics					◇				
Wu / NCAR / HIWIND	Upper Atmosphere						◇			
Fritts / GATS / PMC-Turbo	Heliophysics							◇		
Palestine, Texas	**Summer 18**									
Jones / Princeton / SuperBIT	IR-Submillimeter							◇		
Kogut / GSFC / PIPER	IR-Submillimeter							◇		
Bloser / UNH / ASCOT	Gamma Ray							◇		
Kogut / GSFC / PIPER	IR-Submillimeter							◇		
Fort Sumner, New Mexico	**Fall 18**									
Fischer / GSFC / Big 60 Qual	Test Flight								◇	
Fischer / GSFC / Big 60 Qual	Test Flight								◇	
Moore / GSFC / USIP	tudent Flight Project								◇	
Guzik / LSU / HASP	tudent Flight Project									◇
Kogut / GSFC / BOBCAT	IR-Submillimeter									◇
Chakrabarti / UMass / PICTURE-C	UV / Visible									◇
Toon / JPL / Remote	Upper Atmosphere									◇
Martin / Caltech / FIREBALL	UV / Visible									◇
Kogut / GSFC / PIPER	IR-Submillimeter									◇

FY18 Sweden

Anti-Electron Sub-Orbital Payload – Low Energy (AESOP-lite)

Dr. John Clem, University of Delaware

- Serve as the 1 AU baseline for Voyager Electrons. AESOP-lite will be the only instrument that provides overlapping electron energies.
- Search for origin of turn-up in the low energy electron spectrum. AESOP-lite capable of charge sign separation at these low energies.

HIWIND

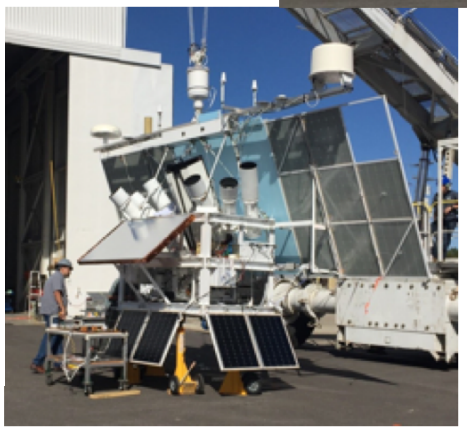
Dr. Qian Wu, High Altitude Observatory, (HAO) NCAR

- Measure polar thermospheric winds.

PMC Turbo

Dr. Dave Fritts, GATS, Boulder

- High altitude turbulence studies by measurements of Polar Mesospheric Clouds (PMCs).
- Test of Balloon Lidar Experiment (BOLIDE).



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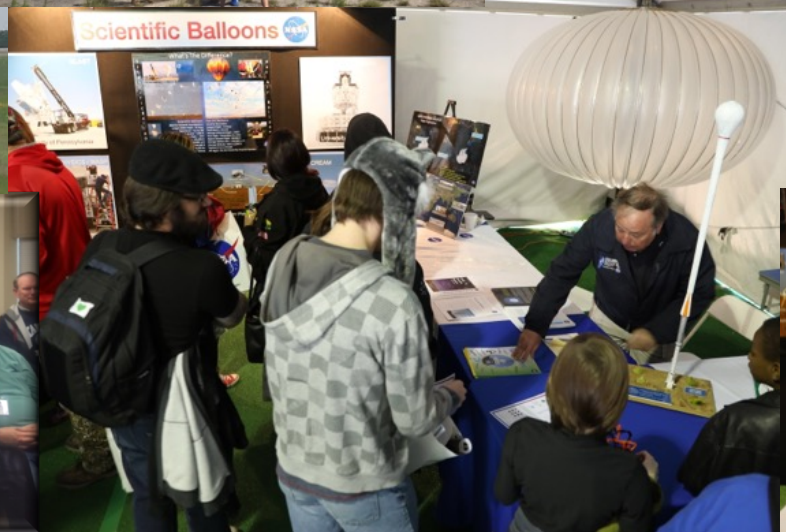
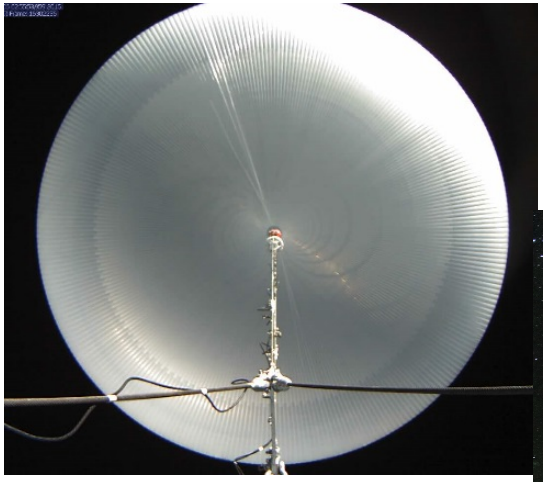
Engaging the Public

Wallops Flight Facility



Summary

- The NASA Balloon Program has continued to provide stable platforms for science.
- The WASP is now an operational support system.
- The SPB development continues.
- Balloons provide an excellent training ground for scientists and engineers



ZP Balloon At Float

Photo by Mike Smith

Flight 590N – ANITA
December 21, 2008

Balloon Specifications

Volume: 0.83 million cubic meter
(29.47 million cubic feet)

Gore Length: 180.6 meters
(592.4 feet)
# of Gores: 159
Film Thickness: 20 micron
(0.8 mil)

Inflated Dimensions
Height: 102 meter (335 feet)
Diameter: 129 meter (424 feet)

Vent Duct Diameter:
3.8 meter (12.6 feet)

SPB By the Numbers

- *Inflated volume ~ 18.8 million cubic feet*
- *Number of Gores = 280*
- *Length of Each Gore ~ 492 feet*
- *Inflated Diameter ~ 376 feet*
- *Inflated Height ~ 233 feet*
- *Shell film thickness ~ 1.5 mil (38 micron)*
- *Final Weight of Balloon > 5,000 pounds*
- *Fitting diameter = 48 inches (4 feet)*
  - *Previously was 58 inches (4.8 feet)*
- *Number of Gore Width Measurements = 6,440*
- *Amount of Load Tape Tendon in Balloon~ 137,760 feet (26 miles)*
- *Amount of film visually inspected, re-rolled and dispensed for this balloon > 1.3 million square feet - over 30 acres of film!*
- *Minimum amount of walking just to seal balloon = 55 miles*

Questions?